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NATIONAL PHOTOGRAPHIC
INTERPRETATION CENTER

TEST AND EVALUATION REPORT

25X1

IMAGE COMPARISON MICROSTEREOSCOPE

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NPIC/R-10/72
SEPTEMBER 1972

[redacted]

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Test and Evaluation Branch
Engineering Support Division

NATIONAL PHOTOGRAPHIC INTERPRETATION CENTER

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ABSTRACT

The Image Comparison Microstereoscope (ICM) was tested and evaluated at NPIC between August 1971 and May 1972. Acceptance tests, operational evaluations, engineering evaluation, and viewing mode evaluation were conducted within this time period.

The instrument provided all viewing modes that were required by the specification. The optical system performed well. The instances in which the ICM did not meet optical specifications did not appear to hamper the use of the instrument by PIs in their evaluation of its operational capability.

Some human-factor deficiencies were noted which would be corrected in future instruments. The ICM exhibited reasonable reliability and presents no problems to internal, routine maintenance with the exception of drive belts for some of the optical switches.

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1. INTRODUCTION

1.1 Background

The prototype Image Comparison Microstereoscope (ICM) is a direct viewing optical instrument with four film chip stages and eight viewing modes. It was developed in response to a need to compare different pairs of stereo imagery. This is the reason for having four stages. An additional purpose was to provide binocular monoscopic viewing modes for experimentation. The viewing modes or ways of examining the various combinations of film chips are defined in section 4.2.

1.2 Test Objectives

The ICM, received in August 1971, was tested by the NPIC Test and Evaluation Branch (TEB) to determine if it met the contractual requirements. There were 21 contractual requirements for the acceptance testing, which was completed in January 1972. Engineering evaluation observations were made during this and other testing. Minor additional engineering tests were conducted by TEB in April 1972. The objective of the engineering evaluation was to evaluate the optical, electrical, and mechanical design of the total instrument. To assist TEB in the engineering evaluation, an independent contractor [redacted] was employed to conduct two studies of the ICM during December 1971 and January 1972. The objective of one study was to produce a performance evaluation of eight viewing modes, both stereoscopic and binocular monoscopic (see section 4.2) using PIs. An additional objective was to determine how the ICM could best be utilized in support of photointerpretation activities and how much improvement it offered over conventional display devices. The objective of the second study [redacted] was to determine the extent to which human-factor principles were incorporated into the design of the ICM.

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Operational evaluations were conducted independently by five operating components [redacted] within their own environment. Photographic materials were furnished to these

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components, by TEB, to demonstrate the ICM's capability. A questionnaire was also prepared to solicit answers as to whether the ICM could contribute to their normal operation and, if so, which modes were most useful. The operational evaluations started in February 1972 and were completed in April 1972.

1.3 Training

The complexity and sheer number of controls on the ICM make it necessary to provide fairly extensive training. The more than ten people involved received one day of lectures and more than one day of hands-on training (or its equivalent). (A few untrained subjects were used for specific and limited tests.) The training was provided [redacted] 25X1

2. SUMMARY OF TEST RESULTS

2.1 General

The ICM test results show it to be a well-liked and useful instrument.

2.2 Acceptance Tests

The optical features of the ICM are generally within 10 percent or better of the requirement. The exceptions were the quality of focus of Stage 3 at low zoom settings, the optical resolution of Stage 1 at high magnification, and the adequacy of illumination for the 1.42X objective at high zoom settings. Switching to the condenser system designed for the 4X objective can alleviate the latter deficiency. The mechanical features of the ICM essentially meet requirements. The functional features such as image rotation and interpupillary adjustment generally more than meet requirements with the exception of the flicker (blink) feature. The maximum flicker rate is less than 15 Hz where 30 Hz was specified. This contractual deficiency is softened by the fact that other tests indicate that a slower flicker rate is desired than the 0.5 Hz minimum that was contractually required. The ICM more than meets safety requirements although the lamp housing surfaces in the kneespace went 21° higher than the specified upper limit of 105° F.

2.3 Other Evaluations

An engineering analysis and evaluation plus five operating component evaluations were conducted. The engineering evaluation included two studies [redacted] The highlights 25X1 of these evaluations are:

- o Operation of the ICM is complex enough to require formal training of an operator to attain efficient use. This training was accomplished by means of a separate contract with the manufacturer. Proficiency on the instrument will decrease if use is not constant but can be regained with minimum effort when the need arises.

- The Blinking Stereo* viewing mode and a monoscopic version of it have been judged the most useful while the Color Comparison* viewing mode and an automatic version of the Blinking Stereo* mode have been judged the least useful.

- An objective performance ranking [redacted] lists the Blinking Stereo* viewing mode and a monoscopic version of it as the top two modes and an automatic version of Blinking Stereo* and Split Field Stereo* as the bottom two. The differences between any two modes were not large enough to be conclusive, however. 25X1

- The minimum flicker rate should be lower. The switching arrangement should be arranged so that both images are presented for a time period in each cycle. [redacted] commented that blink (flicker) systems with fast rise and decay times should be evaluated. 25X1

- There is a need to handle larger film sizes than the prototype ICM will accommodate.

- Some operational components considered the pantograph arms and locking connections between stages unsatisfactory because they could not move the rear stages without disturbing the alignment of the front stages. Emphasis on the proper setup procedures during training should relieve this complaint. The "joystick" controls for fine positional adjustments of the front stages are beyond the psychomotor capabilities of most people but such adjustments are easily made by grasping the front stage directly.

- The off-axis resolution is reasonably good. However, there is significant degradation in resolution off axis when 2.0X anamorphic magnification is used.

*Single asterisks throughout this document refer to the definitions in section 4.2.

- Anamorphic magnification of up to 1.5X was used to achieve stereo with one pair of dissimilar photographs, enabling an experienced photogrammetrist to discover two buildings that were not otherwise detectable. Furthermore, other objects were found to be large boulders and positively not buildings.

- Focusing to the point of blur on both sides of the optimum focus is not always possible.

- The ICM has been judged of average reliability and no problems are expected in routine maintenance with the exception of drive belts. There were three malfunctions in 9 months and one belt had to be replaced twice. These belts, which control optical switches, are difficult to replace.

3. CONCLUSIONS AND RECOMMENDATIONS

3.1 The ICM has been accepted by the operational components as a useful instrument.

3.2 The anamorphic magnification helped achieve useful stereo fusion. However, at the 2.0X maximum setting, it does cause significant degradation of resolution in the off-axis portions of the field of view.

25X1 3.3 [redacted] human-factor evaluation yielded a list of 35 recommendations for improving performance, ease of operation, and operator safety and comfort. It is recommended that they be considered in detail when planning further development.

3.4 The "joystick" controls for fine stage positioning are neither useful nor needed and should be omitted.

3.5 TEB considers that the three "PIC" belt failures indicates a design deficiency and recommends that appropriate corrective action be taken.

3.6 The somewhat inconclusive ranking of the viewing modes may have been affected by deficiencies in the prototype. This should be considered when planning further development.

3.7 Efficient use of the ICM requires about 2 days of training. Maintenance of operator proficiency requires frequent use or a review of training.

4. DESCRIPTION OF EQUIPMENT

4.1 Instrument

The ICM (Figures 1 and 2) is a desk size, direct viewing device with four stages with 5- by 5-inch viewing areas (larger film chips can be accommodated). Optical switches enable a single operator to view any stage binocularly, certain combinations in stereo, and any combination in visual superimposition. Sets of fixed and movable masks permit various split field comparisons of the film chips. The field of view is split vertically so that one film chip or stereo pair is visible in the left portion and another is visible in the right portion. The operator can cause the high intensity stage lamps to turn on and off sequentially using manual or automatic electrical switches. This is referred to as blinking and is used in the various superimposition modes including superimposition of stereo pairs. Ratio control knobs make it possible to change the "OFF" portion of the "BLINK" cycle to be dim instead of completely dark.

Pantograph-linkage systems are provided for both the left and the right pairs of film stages. The linkage systems can be unlocked to allow each stage to be moved independently. Suitable stereo conjugates on the left or right stages can be scanned in stereo when a pair of stages is locked together. The left pair of stages is visible in Figure 1. Normally the left stereo conjugate would be placed on the front stage and the right conjugate on the back stage. The second set of stereo conjugates would be placed in the opposite order on the front and back stages on the right side of the ICM. The linkage systems are designed to enable the operator, while remaining seated, to move the rearmost left and right stages by means of joysticks mounted on the front stages. The left and right linkage systems are visible in Figure 2. The pantograph arms attached to each film stage prevent rotation of the stage during translation. Each stage can be rotated about its center. The front two stages have knobs for fine control of the stage rotation.

Pechan prisms in each of four optical trains permit rotation of the film images. Anamorphic systems in each optical train provide for differential magnification (up

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to 2X) between perpendicular directions in the planes of the film images. Each optical train has an independent zoom system to vary the magnification by a factor of from 0.7 to three. Each stage has interchangeable objectives of 1.42X and 4.0X magnification. With the 10X W.F. eyepieces the total magnification range is about 10X to 120X.

Interchangeable condenser optics are designed to provide proper illumination for the interchangeable objectives. Individual electrical controls vary the intensity of the tungsten filament halogen lamps. Concentric with these controls are the ratio control knobs which vary the intensity of the associated lamp during the "OFF" portion of the "BLINK" cycle. Four small fluorescent tubes around the periphery of each stage provide background illumination to assist in the initial placement of the film chips.

For convenience, numbers have been assigned to the four film stages. The left rear stage is #1. The left front stage is #2. The right rear stage is #3. The right front stage is #4. The optical trains associated with the stages are sometimes referred to as channels. The stage and channel numbers used throughout this report refer to the numbers as given above.

The ICM weighs 750 pounds, is 41 inches deep by 51 inches wide, and is mounted on 5-inch diameter caster wheels. It requires less than 10 amperes of electricity at 60 Hz and 108 to 128 volts.

4.2 Operating Modes

These are the contractual definitions of the required viewing modes. (Asterisks in other parts of this document refer to these definitions.)

- o Alternating Stereoviewing* technique consists of studying a stereo pair, switching mechanically to another stereo pair, and detecting changes by memory recall. (The switching is done by manual operation of two optical switches.)

- o Superimposition* technique consists of binocularly viewing two images simultaneously and detecting differences due to lack of register.

- Split Field Comparison* technique requires a split field whereby two nonstereo images may be viewed side by side.

- Mask Edge Scanning* technique (monoscopic) will allow split field masks to be moved in synchronism over the photographs occluding one and exposing the other.

- Alternate Occlusion (Flicker)* method consists of means to electrically flicker the images to accent changes. (First, one condenser system brightly illuminates one monoscopic image of an optically superimposed pair. Then the illumination from that condenser is greatly reduced as another condenser brightly illuminates the other monoscopic image.)

- Color Comparison* technique consists of color coding the superimposed images with filters to enhance detection of differences due to lack of register.

- Split Field Stereo* method will present two stereo models simultaneously to the operator's field of view, enabling side-by-side comparison.

- Blinking Stereo* method permits alternate occlusion of the two stereo images. (Performed by manual operation of a switch connected to the lamps.)

5. TEST DETAILS

5.1 Acceptance Tests

Optical Features

5.1.1 Image Quality

Design Objectives - Specifications

Image quality should be of the very best, commensurate with that of high quality laboratory microscopes, and essentially free of aberrations and flat of field.

Test Method

Using two square grids (distortion free) obtain stereo fusion and record a description of any false sense of depth. In the superimposition modes, check for nonalignment. Check for on-axis or other astigmatism. Check with both sets of objectives, over the zoom range, through both eyepieces, to all possible stages, and with all eight operating modes.

Test Results

No significant aberrations affecting image quality were detected. The flatness of field is covered in section 5.1.6 (Field of View).

Conclusion

The ICM meets this requirement.

5.1.2 Optical Resolution

Design Objectives - Specifications

A resolution of at least eight lines/mm per power of magnification at 10X shall be provided. The system must resolve 300 lines per mm with the low power objective (1.42X) used at a maximum magnification (for the whole system) of 42.6X. The required resolution is 600 lines per mm with the high power objective (4.0X) used at a maximum system magnification of 120X. The lines/mm per power at any magnification shall not be less than a linear rate of change between these two extremes.

Test Method

Focus at maximum zoom magnification in the center of the field of view using the diopter tester [redacted] and a suitable resolution target. Record the median reading of readings by three observers for each case.

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Test Results

The results of 36 median readings at the lowest magnification was that all 4 channels are within one resolution element (about 12%) of the requirement. At the highest magnification the results varied between one and two resolution elements below the requirement except for Channel 1 which is more than 24% below the requirement. Twenty-four percent is considered greater than the experimental error for this kind of measurement. Typical values for the highest magnification, on axis, are shown in the table.

Optical Resolution** (line pairs/mm)

Channel	Magnification (Maximum)	Eyepiece Left	Eyepiece Right
1	115X	364/325	409/364
2	117X	459/459	NA
3	119X	459/459	515/515
4	121X	N/A	459/459

**The first number in the Eyepiece columns is for resolution target bars perpendicular to the observer's eyebase. The second number is for bars parallel to the observer's eyebase.

At the intermediate magnifications (about 27X and 47X), 72 median readings showed only one out-of-specification reading.

Conclusion

Except for Channel 1 the ICM meets this requirement.

5.1.3 Stage Illumination

Design Objectives - Specifications

A high-intensity condenser-type source shall be provided beneath the surface glass plate of each chip stage. This source shall be designed for and mated with the microscope to insure maximum performance from the optical viewing system. At full intensity, the high-intensity source must provide adequate illumination of a film area with an average density of 2.5 units as viewed through the optical system at both eye stations while operating at a magnification of 120X. All other magnification settings shall be equally well illuminated. The source for each stage shall operate at a temperature between 3500K and 5500K. Means shall be provided for continuously varying the illumination from 50% to 100% of full intensity of each independent high-intensity source. Such reduction shall not bring the apparent Kelvin temperature below 3500K. Separate controls varying the intensity of illumination of each separate stage plate shall be provided. In addition, a Ratio Control will control the intensity in the dim portion of the flicker cycle in the Alternate Occlusion* mode. Two condensing systems will fill the largest useful field (20 mm) and the largest useful aperture (0.106NA) of the 1.42X relay objective and the largest useful field (7 mm) and the largest useful aperture (0.202NA) of the 4X relay objective.

Test Method

Measure the correlated color temperatures at 50% and 100% of full intensity from each stage with each condensing system using the Gamma Scientific Inc. Model 3000 spectroradiometer. Measure the light intensity through the eyepieces at various magnifications relative to that at 120X. Obtain an opinion from three PIs as to the adequacy of the illuminator when viewing imagery (of the maximum available average density in the FOV) at 120X. Check the other features.

Test Results

The 38 measurements of color temperature ranged from 4090K to 5360K. Two condenser lens systems are provided for the high-intensity light source for each stage. The last lens surface of each condenser lens system for the 1.42X objectives has been partially converted into a diffusing surface, which essentially changes the character from a condenser-type to a diffuser-type light source. The numerical apertures (N.A.) are 0.1 for the 1.42X objective and 0.2 for the corresponding condenser. The N.A.'s are 0.2 for the 4X objective and 0.1 for its corresponding condenser. The PIs agreed that the illumination through the 1.42X objective (and film imagery) from the matching system is questionable (marginal) when used at 40X. The average density of the imagery ranged from 1 density unit (d.u.) to no more than 1.7 d.u. No imagery (black and white) of 2.5 d.u. (standard diffuse transmission density) was available. Changing to the condenser for the 4X objective or going to lower magnifications produced satisfactory illumination. The condensers do fill the fields of view as required. The Ratio Controls meet the requirement. Another test showed that using the Pechan prism to rotate the image can decrease the light level by as much as 30%. This light level decrease would degrade the adequacy of illumination still more.

Conclusion

The ICM does not meet this requirement.

5.1.4 Focus

Design Objectives - Specifications

Independent focus shall be provided for each chip stage. Both a coarse and a fine focus shall be provided. A means shall be provided to adjust for the differences in focus between the left and right eye of the operator.

Test Method

Check at one nominal interpupillary distance setting. Adjust the eyepiece foci on the discrete numerical digits and on one rear stage in a binocular mode. Focus on the other stages with the independent coarse and fine foci of the objective lenses. Check with both sets of objectives, over the zoom range, through both eyepieces, to all possible stages, and with all eight operating modes.

Test Results

Independent coarse and fine focus controls were provided for each of the four sets of objectives. Both eyepiece tubes can be focused independently. The quality of focus was good except for the low zoom settings of Channel 3 (the right rear stage).

Conclusion

It is questionable whether the ICM meets this requirement.

5.1.5 Magnification

Design Objectives - Specifications

The instrument shall provide zoom-type, continuously variable, 10X to 120X magnification by means of zoom elements, 10X fixed eyepieces, and self-contained interchangeable objective lenses. The total range in magnification is to be 10X to 42.6X with the 1.42X first relay objective, the 0.7X to 3.0X zoom system, and the 10X eyepiece. The total range in magnification is to be 28X to 120X with the 4X first relay lens, the 0.7X to 3.0X zoom system, and the 10X eyepiece. Between 28X and 42.6X the magnification ranges overlap.

Test Method

Count the number of divisions of a stage micrometer (as seen through the eyepiece) that match a suitable number of divisions on a scale 10 inches from the other eye. The ratio of distances is the linear magnification. After one or more such measurements, intercompare with both sets of objectives, over the zoom range, through both eyepieces, to all possible stages, and with all eight operating modes.

Test Results

The ICM is within about 5% of the requirement.

Conclusion

Essentially meets the requirement.

5.1.6 Field of View

Design Objectives - Specifications

The widest, usable, flat field of view that can be optically obtained is a design goal. The maximum field coverage of the low power objective (1.42X) is to be 20 mm. The maximum coverage for the high power objective (4.0X) will be 7.14 mm.

Test Method

Record the visible range on a stage micrometer at three equiangular directions across the field of view. Measure the field flatness at 0.8 of the eyepiece field position in terms of the refocusing required from the on-axis position. Check with both sets of objectives (at the lowest zoom setting) through both eyepieces, to all possible stages, and in the stereo and superimposition modes.

Test Results

The most frequent values for the fields of view were 18.6 mm and 6.9 mm taking all viewing modes together. These values are within 7% of the requirement, although the entire field of view is not always usable. Up to 0.01 inch refocusing movement of the 4X objective lens is required to bring the area at 0.8 of the field of view into focus. From 0.05 to 0.08 inches refocusing movement of the 1.42X objective lens is required for all but Channel 3, which cannot be focused on the area at 0.8 of the field of view.

Conclusion

It is questionable whether the ICM meets this requirement.

5.1.7 <u>Anamorphic</u>

Design Objectives - Specifications

The optical system for each of the four inputs shall incorporate anamorphic correction that is continuously variable from 1.0X to 2.2X. The direction of anamorphic stretch is to be rotatable through 360°.

Test Method

Use a grid on one film stage and a scale on another suitable stage. In the superimposition or split field modes, direct anamorphic magnification comparisons can be made. Rotate the axis of anamorphic stretch through 360° or to its limits and record.

Test Results

The 12 measured maximum anamorphic magnifications were 2.0X with two exceptions of 2.06X. The anamorphic correction controls had unlimited rotation of the stretch axes. The ICM is within 10% of the requirement.

Conclusion

Essentially meets the requirement.

Mechanical Features

5.1.8 Construction

Design Objectives - Specifications

Construction shall meet the highest standards of microscope design.

Test Method

Inspect for interfering scratches, digs, and stains that are visible during use. Inspect for any lint, grease, oil, dirt, or scum that interfere with visual use and that cannot be easily cleaned off. Formulate and record opinions on the structural ruggedness of the microstereoscope and its components.

Test Results

Nothing appeared to interfere with visual use. The structural ruggedness of the microstereoscope, and its components appeared to be satisfactory to the test engineer.

Conclusion

The ICM meets this requirement.

5.1.9 Stage Translation

Design Objectives - Specifications

Each chip stage shall have independent translation in the X and Y directions to allow adjustment of relative chip positions. Independent stage travel shall not be less than

±3.55 inch in both the X and Y directions. A common translating motion shall be incorporated to allow the left pair or the right pair of stages to be moved simultaneously in the X direction and in the Y direction. The stage motion must have low friction and must be smooth, positive, and chatter free. Operation shall be by means of a fine control.

Test Method

Measure the range of independent X and Y motion of each stage by observing (at low power) a scale on the stage using the crosshairs of the diopter tester or edge of the field of view as the reference mark. Repeat for the other stages. Record opinions of smoothness, positiveness, and ease of movement of the stages. (NOTE: Stage rotations should be at 45° for these tests.)

Test Results

The average value of 17 measurements is within 1% of the required ±3.55 inches. The smoothness and ease of movement were judged to be good. The positiveness of stage movement was good except for a backlash of 0.01 to 0.05 inches. The mechanical joysticks that were provided as the fine controls were unsatisfactory. However, fine control was found to be unnecessary.

Conclusion

The ICM essentially meets this requirement.

5.1.10 Film Hold-Down

Design Objectives - Specifications

Film chip hold-down will be by means of a 1/4-inch glass pressure plate over the film. Its weight will provide sufficient force to hold the film flat without spring loading and without scratching or marking the film. The glass will be of sufficient optical quality so as not to degrade the imagery.

Test Method

Mount and demount typical film chips on each stage. Check the film chips for new scratches and marks. Check the thickness of the plate. Check the flatness of curled film chips that have been kept rolled around a pencil.

Conclusion

The ICM meets this requirement.

Functional Features

5.1.11 Split Field

Design Objectives - Specifications

A means for viewing in the Split Field (nonstereo) Comparison* mode will be provided. A means for Mask Edge Scanning* (traveling split field) and a stationary Split Field Stereo* mode will be provided. The Split Field Stereo* images will be oriented correctly (in relation to the two front stages) when the image rotation controls are at their nominal zero positions. It shall be a design goal that the Mask Edge Scanning* image will also be oriented correctly (left-right).

Test Results

Correct left-right orientation of the images in the Mask Edge Scanning* mode is not obtainable for the stage combinations 1-4, 2-3, and 2-4. Otherwise modes operate as required.

Conclusion

The ICM meets this requirement. (The left-right orientation was only a design goal.)

5.1.12 Image Rotation

Design Objectives - Specifications

Optical image rotation of 360° shall be provided for each of four input images.

Test Results

Image rotation for three of the channels is unlimited. Channel 1 has a range of rotation of 580°.

Conclusion

The ICM more than meets this requirement.

5.1.13 Image Selection

Design Objectives - Specifications

It shall be possible to view the images as follows: left front, left rear, and right rear through the left eyepiece; left rear, right rear, and right front through the right eyepiece. This system of optical switching shall provide the maximum optical movement from a minimum control movement.

Test Results

Stages 1, 2, and 3 can be seen through the left eyepiece as required. Stages 1, 3, and 4 can be seen through the right eyepiece as required. The control movement involves a 79° rotation of one or two 5.8 cm levers.

Conclusion

The ICM meets this requirement.

5.1.14 Independent Zoom

Design Objectives - Specifications

The optical image path for each of the four photos shall provide independent zoom magnification.

Test Results

The four zoom systems do operate independently.

Conclusion

The ICM meets the requirement.

5.1.15 Interpupillary Adjustment

Design Objectives - Specifications

An adjustment for variation in interpupillary distances between 52 and 74 mm shall be provided together with an easily readable graduated scale to indicate actual millimeter setting. The interpupillary adjustment shall be provided with a positive lock.

Test Method

Use typical settings for the eyepiece and objective lens foci. Suspend a ground glass screen (or equivalent) over the eyepieces so that small sharp exit pupils are made visible. Measure the distance between the centers of the exit pupils. Check with both sets of objectives, over the zoom range, through both eyepieces, to all possible stages, and with all eight operating modes.

Test Results

The measured interpupillary distance was 51 mm minimum and 74 mm maximum for all configurations. A graduated millimeter scale and a positive lock were provided.

Conclusion

The ICM more than meets this requirement.

5.1.16 Flicker

Design Objectives - Specifications

An electrical means for occluding one or both images alternately will be provided. The rate of occlusion will be variable (by the operator) between 0.5 Hz and 30 Hz. A form of this alternate occlusion will be usable for stereo comparison. A ratio control will control the intensity in the dim portion of the flicker cycle in the Alternate Occlusion* mode. Full counterclockwise rotation of the BLINK RATE control will hold all four lamps on continuously. The intensity of each lamp will be dependent upon the setting of its INTENSITY control. When the STEREO BLINK switch is moved to its ON position, the left stage lamps are paired together and the right stage lamps are paired together. With the AUTO./MAN. switch in the AUTO. position, the two selected lamps (or pairs of lamps) will blink on and off at the frequency set by the BLINK RATE control. In the MAN. position the LEFT/RIGHT switch will light the left or right lamp or pair of lamps.

Test Method

Measure the flicker rates with an optical sensor and an oscilloscope. Observe the oscilloscope trace while varying the Ratio Control to judge whether or not it works. Check the other features.

Test Results

The flicker rates varied from 0.58 to 0.63 Hz (16 measurements) at the slow end and from 14.0 to 14.3 Hz (8 measurements) at the fast end. The flicker rate was easily variable between these values. The Ratio Control and other features do operate. Full counterclockwise rotation of the BLINK RATE control did not hold all four lamps on continuously.

Conclusion

The ICM does not meet this requirement.

Safety Features

5.1.17 Shock Hazard

Design Objectives - Specifications

The ICM must be grounded and free of all hazards.

Test Method

Measure the leakage current with the [redacted] 25X1
25X1 [redacted] Leakage Current Tester in all electrically significant configurations. The microstereoscope will be connected to a
25X1 [redacted] Ground Fault Circuit Interrupter. Should this unit be tripped, the shock hazard will be re-evaluated.

Test Result

The highest leakage current measured was 0.29 ma with the power switch turned off, the electrical plug reversed, and the ICM ungrounded. All other electrical configurations yielded less leakage current. The most stringent ASA requirement (for portable devices) is 0.5 ma. The ground fault circuit interrupter set to trip at 3.4 ma was never tripped during the extensive acceptance tests.

Conclusion

The ICM more than meets this requirement.

5.1.18 Warning Light

Design Objectives - Specifications

A warning light must be provided to show when the power supply to the unit is switched to ON.

Conclusion

The ICM meets this requirement.

5.1.19 Heat

Design Objectives - Specifications

The temperature on the normal operational surface of the instrument shall not exceed 105° F after operating at maximum intensity over a 24-hour period in a room with an 80° F ambient temperature. The temperature of a film chip with an average density of 2.5 placed on the stage and illuminated at maximum intensity will not exceed 120° F.

Test Method

Place disposable film chips having average densities of 2.5 density units emulsion side up on each stage. Operate at maximum intensity for 24 hours in a room or enclosure at 80° F. (NOTE: Preliminary temperature measurements during the 24-hour operating period may show that the film temperature is so far above or below the 120° F limit that this test may reasonably be terminated.) Probe the normal operating surfaces for the hottest areas and get estimates of the surface temperatures that exceed or are close to 105° F.

Test Results

The hottest parts of the ICM that the operator is likely to contact are the lamp housing plates in the operator's knee-space. The temperature of the left one exceeded 126° F. All other positions, including the 2.5 d.u. test film chips were well within the requirement.

Conclusion

The ICM does not meet this requirement because the lamp housing plates exceed 105° F.

Convenience Features

5.1.20 Image Selection Indicator

Design Objectives - Specifications

Discrete numerical digits to indicate to the operator which of the images he is viewing will be provided. They will be sandwiched between two glass cemented substrates so that dust particles in the image plane will be eliminated. The indicators must remain in focus throughout the magnification range and must not substantially intrude into the field of view.

Test Method

View each numerical indicator with one eye and compare with a scale that is 10 inches from the other eye. Set each anamorphic ratio at its maximum setting. Rotate the axis of anamorphic stretch through 360°. Record any intrusions into the fields of view and any defocusing of the numerical indicators.

Test Results

The numeral 1 for Channel 1 intrudes from 10% to 20% into the field of view as the axis of anamorphic stretch is rotated. The numeral 3 for Channel 3 goes partly out of the field of view as the axis of anamorphic stretch is rotated. The numerals disappear when covered by masks and when backed by dark imagery. This disappearance is considered unavoidable without undue expense and is relatively unimportant.

Conclusion

The ICM does not fully meet this requirment because of the Channel 3 numeral going partly out of the field of view.

5.1.21 Background Illumination

Design Objectives - Specifications

Backgound illumination shall be provided for each of the stages to facilitate orienting film chips on the stages. Four T5 4-watt fluorescent lamps shall be located around the periphery of the free aperture of all four stages.

Test Method

Attempt to obtain specific orientations of the film chips using background illumination only. Check the switch and lamps.

Test Results

There are two switches per stage and four T5 4-watt fluorescent lamps per stage. The background illumination is sufficient for orienting film chips on the stages except when the color filters are in place.

Conclusion

The ICM partially meets the requirement.

5.2 Operational Evaluations

Each of the four operating components of [redacted] 25X1
and APSD/TSG used the ICM for a week or longer. Generally, the personnel who evaluated the ICM were from the trained group (referred to in 1.3) or were in turn trained by them.

The ICM provided a variety of viewing modes for evaluation. The opinions of the operating components varied as did those of the personnel within the components. However, they generally ranked six of the eight contractually required viewing modes, in order of usefulness, as:

Split Field Stereo*
Split Field Comparison*
Superimposition*
Mask Edge Scanning*
Blinking Stereo*
Alternate Occlusion (Flicker)*

The Alternating Stereoviewing* mode was not evaluated, apparently because the Blinking Stereo* mode was so much easier to use. The Color Comparison* viewing mode was not used in the operational evaluations. It had been previously concluded that large contrast differences between two film coverages tended to obscure differences due to missing objects. Therefore, change detection was easier without the color filters. The filters were not made available to the operating components during the operational evaluations. One component tested a four-image superimposition viewing mode for signal to noise enhancement with no success.

This subjective ranking should be used with caution as should the objective ranking given in section 5.3.5.

The operating components were dissatisfied with the present arrangement of pantograph arms and locking connections between stages for two reasons. Some PIs with short arms found it difficult to move the rear stages independently of the front stages while looking through the eyepieces. However, proper emphasis on the setup procedures during training should eliminate the need for independent movement of the rear stages. There is some slight relative motion between linked stages which hinders scanning in stereo. However, stereo scanning is not a requirement of the prototype ICM, especially at high magnification.

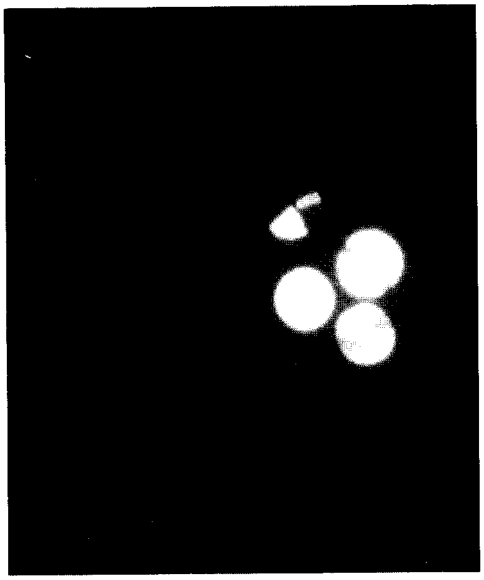
Two of the components commented on the need to handle larger film sizes than the prototype ICM will accommodate. The blink (flicker) rate was generally considered to be too fast even at its lowest rate. One component reported that the eyepieces did not stay firmly in place when being focused. Another component stated that the eyepiece unit should be redesigned so that existing filar eyepieces can be inserted and used. A number of other human-factor type comments were made. However, all of the operating components concluded that the ICM was a good instrument.

5.3 Engineering Analysis and Evaluation

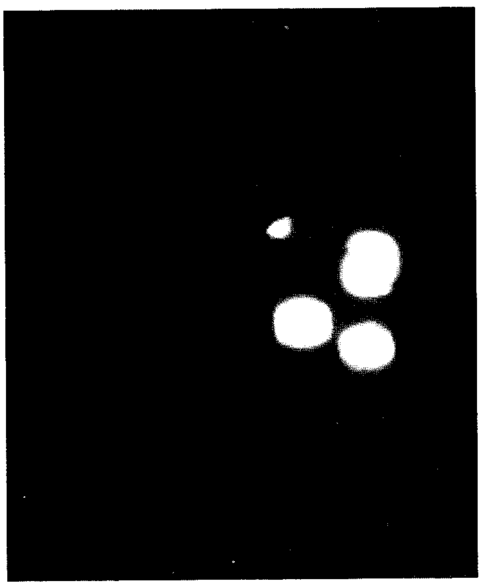
5.3.1 Exit Pupils

An introduction to this subsection is necessary to warn the nontechnical reader that the photographs (Figure 3) of the exit pupils are not directly relatable to what the eye sees at the film plane. In fact, it was found that with the ICM controls set for the worst case (Figure 3.a), the edges of the four fields of view at the film plane were misaligned by less than 2 percent of the 1.32 mm diameter of the fields of view at 115X total magnification.

The exit pupil can easily be made visible by placing a diffusing screen at a distance above the eyepiece equal to the exit pupil height. The size and position of the exit pupil or pupils can then be measured directly or photographed. Figure 3 consists of enlarged photographs of the exit pupils from the right eyepiece of the ICM for various settings. Figure 3.a and b show the effect of the anamorphic magnification control. Figure 3.a and c show the extremes of exit pupil superimposition occurring with image rotation changes. Figure 3.d shows the degree of superimposition for the base



a) Zoom Max.
Objective 4.0X
Anamorphic Mag. 1.



b) Zoom Max.
Objective 4.0X
Anamorphic Mag. 2

Figure 3. Typical Range
enlargement) a) and b)
tion controls set at th

configuration (image rotation controls set at their nominal zero positions). Figure 3.e and f show the respective exit pupil sizes for the 1.42X objective at high zoom and the 4.0X objective at low zoom (about 47X and 27X). Note that the range of exit pupil sizes for the 4.0X objective of the ICM is 0.6 to 1.8 mm. The 1.42X objective at low zoom gives 1.9 mm. Note also that the separated exit pupils shown in Figure 3.a, b, c, and d fall within an area smaller than the usual sizes of the human iris as given by the Human Engineering Design Guide for Image Interpretation Equipment,
25X1 [redacted] dated August 1971 (p. 4-10).

The effect of the separated exit pupils could be noted whenever the observer moved his eye an appreciable amount from the optical axis. The imagery on the stage corresponding to whichever exit pupil was masked by the observer's iris would disappear from view while the other stage imagery would remain in view.

The exit pupil for stage #4 remained in the same position when the image rotation control was moved through its range. However, the exit pupils for the other three stages traced circles of appreciable size as their respective image rotation controls were moved, indicating the existence of some residual misalignment.

It has been suggested that a reasonable criterion for exit pupil separation might be that their centers fall within a 2 mm diameter circle. A study of this problem is planned under NPIC sponsorship.

The cutoff of the exit pupil for stage #2 (shown in Figure 3.a) was studied. A quick check of the optical resolution showed a nearly 50 percent decrease when stage #2 was in the worst position (image rotated about 150° from the nominal zero). This vignetting has since been corrected.

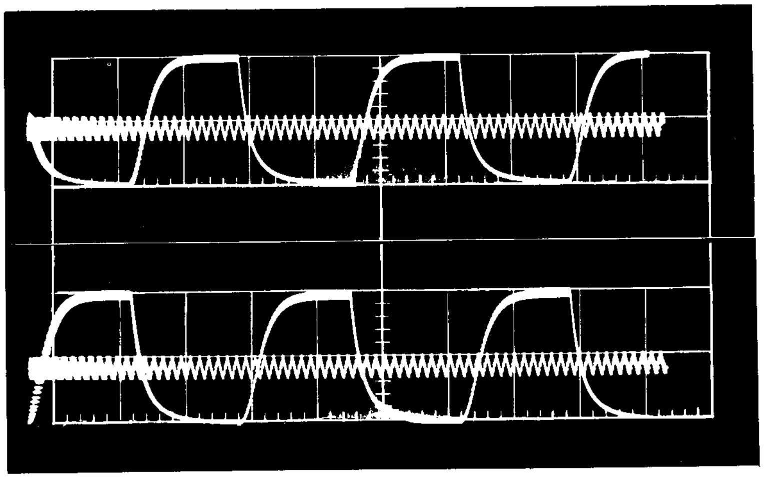
5.3.2 Automatic Blink

The ICM Operation Manual [redacted] explains how to set up 25X1
the Blinking Stereo* (called Alternate Stereo [redacted] and 25X1
Alternate Occlusion (Flicker)* modes for automatic blinking of the condenser lamps.

The normal expectation would be that an electronic system for interrupting the illumination to a stage would approximate a square wave. The large amplitude, lower frequency traces in Figure 4.a and b do not meet this expectation. In addition, Figure 4.a and b show that at the higher flicker (blinking) rates the light level amplitude severely decreases and the light level ceases to go to zero. Because the users generally desired a slower flicker rate than was provided on the ICM, these deficiencies may have no operational effect. However, an improved version of the automatic blink system may well create a need for the higher blink rates.

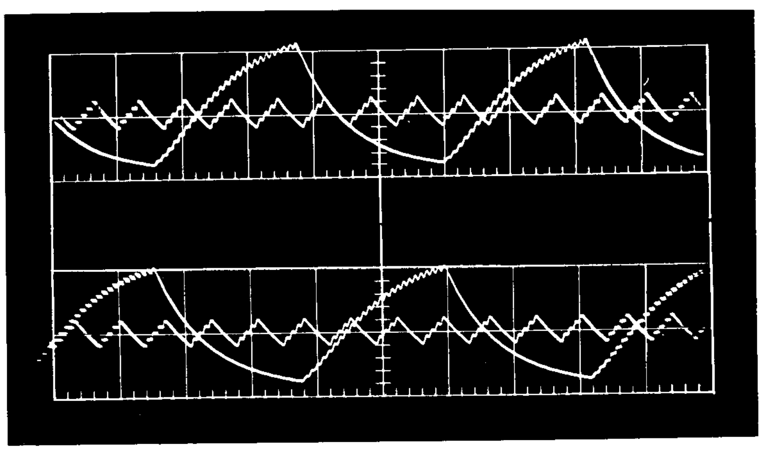
No provision was made for varying the time of overlap between the stages that are to be alternately illuminated. Such provision may be needed if slower flicker rates are provided for future models. The contractor's proposal cited the need for some overlap.

Max.
Stage 2
0
Max.
Stage 4
0



a) Trace speed: 2 cm/sec
Flicker rates: 0.6 and 14.1 Hz

Max.
Stage 1
0
Max.
Stage 2
0



b) Trace speed: 10 cm/sec
Flicker rates: 2.3 and 14.1 Hz

Figure 4. Oscilloscope Traces of Relative Light Levels versus Time.

5.3.3 Off-Axis Resolution

The off-axis resolution readings were made at 0.7 of the distance from the center of the field of view to the edge of the field of view. The off-axis readings listed in Table 1 were made variously at the top, bottom, left, and right parts of the field of view. The acceptance criteria assigned to the on-axis contractual requirement is based on the experimental error associated with optical resolution measurements. The experimental error is one or two elements on the 1951 USAF Tribar target. This target is based on a $\sqrt[6]{2}$ ratio between elements. This ratio yields 24 percent for a two-element difference. Therefore, the on-axis contractual requirement was decreased by 24 percent to give the acceptance criteria that are listed in Table 1, sixth column.

Due to the importance of both off-axis resolution and the anamorphic adjustment feature, a fairly extensive sampling of data is listed in Table 1. Comparison of the on-axis 2.0X anamorphic magnification column with the acceptance criteria and the 1.0X columns shows that the ICM either meets the criteria or is only slightly worse with anamorphic magnification than without. A similar comparison for the off-axis readings with no anamorphic stretch shows that the ICM either meets the criteria or is only slightly worse off axis than on axis. In the off-axis case with 2.0X anamorphic stretch, 9 out of 24 readings do not meet similar conditions. Therefore, the ICM is deemed to have significant degradation at 0.7 of the field when maximum anamorphic magnification is in use.

The fact that the ICM has only this much degradation of optical resolution was unexpected. However, a rationale can be developed which partially explains this phenomenon. The 1951 USAF Tribar target is based on sets of bars having a 5:1 length-to-width ratio. The anamorphic magnification changes this ratio because it is a one dimensional magnification. It is well known that long bars or lines are more easily resolved by the eye than are short ones. Therefore, when the direction of the anamorphic stretch is such that it lengthens the image of the bars, the effect of the eye is to resolve finer resolution elements than would be the case if the length-to-width ratio had been kept constant. When the direction of anamorphic stretch magnifies the width of and the spacing between the bars, it is reasonable to expect the eye to resolve finer resolution elements despite the adverse change in the length-to-width ratio of the bars. This extra one dimensional magnification

TABLE 1. OPTICAL RESOLUTION (LINE PAIRS/MM)

STAGE	TOTAL MAG.	EYE-PIECE	90 DEGREE IMAGE ROTATION	ON-AXIS REQUIREMENT (ANAMORPHIC MAG. 1.0X)	CONFIDENCE LEVEL (LOWER) ASSIGNED TO REQUIREMENT	ANAMORPHIC MAGNIFICATION 1.0X ON-AXIS	ANAMORPHIC MAGNIFICATION 1.0X OFF-AXIS	ANAMORPHIC MAGNIFICATION 2.0X ON-AXIS	ANAMORPHIC MAGNIFICATION 2.0X OFF-AXIS
3	10.5X	RIGHT		82.4	62.6	72/72	(NOT IN FOCUS AT 2.0X ANAMORPHIC MAGNIFICATION)		
4	10.7X	RIGHT		83.3	63.3	91/91	57/72		
4	10.7X	RIGHT		83.3	63.3	91/91	72/64		
4	28X	RIGHT		132.4	100.6	258/258	143/128		
4	28X	RIGHT		132.4	100.6	258/258	143/114		
1	42X	LEFT		198.7	151.0	289/289	228/181	258/289	228/81
1	42X	LEFT	X	198.7	151.0	289/289		289/258	143/114
1	42X	RIGHT		198.7	151.0	229/205	181/203	258/258	181/114
1	42X	RIGHT	X	198.7	151.0	258/258		258/258	
1	42X	RIGHT		198.7	151.0		181/161		
2	46X	LEFT		250.3	190.2	289/269		258/258	228/181
2	46X	LEFT	X	250.3	190.2	258/258		258/258	228/228
3	46X	RIGHT		250.3	190.2	229/229	181/228		
4	48X	RIGHT		259.7	197.4	289/289	228/256		
4	48X	RIGHT		259.7	197.4	289/289	228/228		
2	80X	LEFT		378.4	287.6				406/362
1	115X	LEFT		576.6	438.2	364/325	406/406	409/325	512/456
1	115X	LEFT	X	576.6	438.2	364/459			406/362
1	115X	RIGHT		576.6	438.2	409/364		459/325	512/406
1	115X	RIGHT	X	576.6	438.2	364/409			456/362
2	117X	LEFT		586.1	445.4	459/459		459/459	456/406
2	117X	LEFT	X	586.1	445.4	409/459			456/406
4	121X	RIGHT		605.0	459.8	459/459	456/512		
4	121X	RIGHT		605.0	459.8	459/459	456/456		

is not incorporated in the report as a change in the total magnification of the system. Resolution readings using the 1951 USAF Tribar target are based on a 5:1 length-to-width ratio and are of unknown validity for other ratios.

5.3.4 Anamorphic Magnification

For this evaluation a pair of low altitude photographs, which could not rightly be called stereo conjugates, were used. These photographs were placed on stages #1 and #2 of the ICM. The ICM was set up as shown in Table 2.

Table 2

	Stage #1	Stage #2
Total Magnification	12.5X (nominal)	10X (nominal)
Anamorphic Magnification	1.05X	1.5X
Orientation of Anamorphic Stretch	10° to 12° CW	about 15° CCW
Image Rotation	150° CW	135° CW

The test subject (an experienced photogrammetrist, but untrained on the ICM) and the test engineer could see stereo which was not possible before. With these settings the test subject distinguished two buildings not seen without stereo fusion. Furthermore, other objects were found to be large rocks and positively not buildings.

5.3.5 Viewing Modes Evaluation and Human-Factor Studies Boeing

The viewing modes of the ICM are not simple to set up, and the uses of these various modes may not be apparent to the untrained PI. Consequently, TEB requested a structured test to insure that selected modes would be used and a statistical determination of the value of each could be made. This was to be done in addition to a human-factors study and the normal NPIC operational evaluation. Experienced PIs who are accustomed to using stereo techniques were used as test subjects. The problems to be worked on the ICM were solicited from operational components [redacted] 25X1

This work was done [redacted] under contract with NPIC. The results are given in a two-volume document, DK-820, dated March 1972: Image Comparison Microstereoscope (ICM), Volume I - Operational Suitability Evaluation (SECRET); and Volume II - Human Factors Evaluation (Unclassified). 25X1

Volume I contains material on the uses of the ICM in support of PI activities and the measurements of improvement over a conventional technique. It states that training on the ICM is essential for efficient operation. Even a well trained operator must have review material available if he or she has not used the ICM frequently or recently. The performance of selected viewing modes in change detection was evaluated. Some of the viewing modes which were required by the development contract (e.g. Alternating Stereoviewing*)
25X1 were excluded [redacted] from the viewing mode evaluation. Limited resources, both in test planning and PI time, were available. Those modes which were not extensively used and evaluated were considered [redacted] to be adequately 25X1
covered by tests on similar modes. Two new versions of the Blinking Stereo* viewing mode were evaluated as the contractor's experience indicated their potential value. (Note that the viewing mode terminology has been converted
25X1 from that of the [redacted] report to that of the development contract, section 4.2.) However, the results overlapped to the extent that one should be cautious in using them for decision making. In addition to the objective performance data, the contractor gathered subjective data during the performance tests and some specific applications. The ranking (combined) from the most useful to the least useful is:

Blinking Stereo*
Monoscopic version of Blinking Stereo*
Mask Edge Scanning*
Alternate Occlusion (Flicker)*
(Conventional**) 1540 Light Table/Zoom
    240 Microstereoscope
Split Field Stereo*
Automatic Version of Blinking Stereo*

**One of the operating components commented that selection of the 1540/240 combination for the standard of comparison could lead to misinterpretation of the test results because their PIs choose from a variety of PI tools those most suited to each problem.

The contractor had previously concluded that the Color Comparison* viewing mode would not be useful for change detection and therefore it was excluded from the viewing modes evaluation by PIs [redacted] also concluded that the ICM is a special purpose viewing device, not a replacement for the Zoom 240 Microstereoscope. In addition to the four-stage version of the ICM, a two-stage version with Alternate Occlusion (Flicker)* and Mask Edge Scanning* viewing modes would be useful for PI activities. PIs should use the stereo capabilities for determination of the structure of complex equipment, looking for differences between objects of the same class, and identification of unknown objects by comparison with known objects, especially when working at the resolution limit of the imagery. Monoviewing modes should be used when simply detecting changes between successive photographs.

25X1

Volume II of the [redacted] study contains 35 recommendations to improve the human-factor characteristics of the ICM. To indicate the extent to which human-factor principles were used in the design of the ICM, the more important recommendations will be cited here followed by the positive comments.

25X1

- o Improve the exit pupil alignment if possible.
- o Add a variable aperture to reduce the field of view to aid in viewing small objects.
- o Increase the illumination level for the low-power objectives.
- o Evaluate a blink (flicker) rate system with fast rise and decay times.
- o Make a reticle eyepiece available as an aid in aligning images.
- o Provide a better method of moving the rear stages.
- o Objective lens focusing should be adjustable to the point of blur on either side of the point for optimum focus.

The good human-factor features that are incorporated are:

- o Provision of a useful headrest.
- o A nominal magnification range of 10X to 120X (the entire range was used).
- o Anamorphic magnification.
- o Optical rotation (was essential).

- Color coding and numbering of the film stages and controls.

- Stage linkage made it possible to regain stereo with little effort after the stages were moved up to several fields of view.

5.3.6 Reliability and Maintainability

During approximately 6 months of average use, three FCS quartz halogen lamps were replaced. Lamps of this type have the relatively short life at maximum intensity of 50 hours. However, the ICM limits the maximum socket voltage to extend lamp life.

The pantograph arms and locking connections between stages are designed to permit movement of these stages simultaneously. There is some slight relative motion between linked stages. The locking devices which tie two stages together can be adjusted to eliminate any relative motion not attributable to bearing surfaces and joints in the linkages.

Use of the joysticks intended to make the final positional adjustments of the front stages, is beyond the psychomotor capabilities of most people. It requires too much muscular effort and coordination to force the joystick down in one direction and simultaneously move it slowly in another direction. The final positional adjustments were satisfactorily accomplished throughout the test program by simply grasping the front stage directly.

The "PIC" belts which change the internal rhomboid position failed three times, twice on the left side and once on the right. They are difficult to replace as extensive disassembly of the ICM is required. Some redesign is indicated to prevent this from recurring. These belts probably were overstressed when an endpoint of the rhomboid travel was reached and the actuating levers were forced an additional distance. It should be noted, however, that the ICM has been used extensively for training as well as for testing of its performance. The ICM is sufficiently complex that the number and types of failures experienced is considered to indicate average reliability.

The Equipment Performance Branch at NPIC judged that routine optical, electrical, and mechanical maintenance of the ICM will present no problems.

25X1

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